enerSave
For Municipalities

Saving Energy in the Vehicle Fleet

Energy, Mines and Resources Canada
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Contents

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Saving Energy in the Vehicle Fleet

Introduction

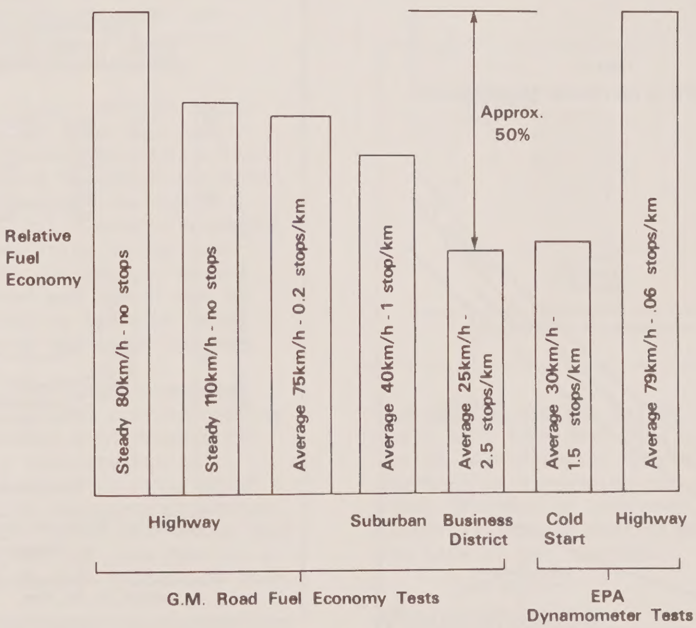
With proper vehicle specification, good management and common sense, municipalities can achieve fuel savings of up to 25% in the operation of their motor vehicle fleets. Today this reduction in fuel consumption translates into increasingly important dollar savings. Furthermore, most of these savings can be realized without major capital expenditures or any significant sacrifice in current levels of service.

This section provides the basis of a comprehensive municipal fleet management program, with fuel-conserving techniques organized under two main headings: Fleet Operations and Equipment Selection.

The first item, improving fuel economy through fleet operations, essentially means taking steps to minimize waste of gasoline in the operation of the existing fleet. These steps include promotion of fuel-conscious driving habits and attitudes, proper vehicle maintenance, efficient vehicle utilization, a system to record and monitor fleet fuel consumption, efficient

TABLE 1

TYPES OF DRIVING VERSUS FUEL ECONOMY



Source: "Fuel Economy Trends and Catalytic Devices", Automotive Fuel Economy, Progress Technology Series, Vol. 15, 1976.

organization of work assignments and decentralization of administration/maintenance facilities where possible.

The second item, improving fuel economy through equipment selection, means choosing the right type of vehicle for each application and setting proper specifications for equipment and add-on devices.

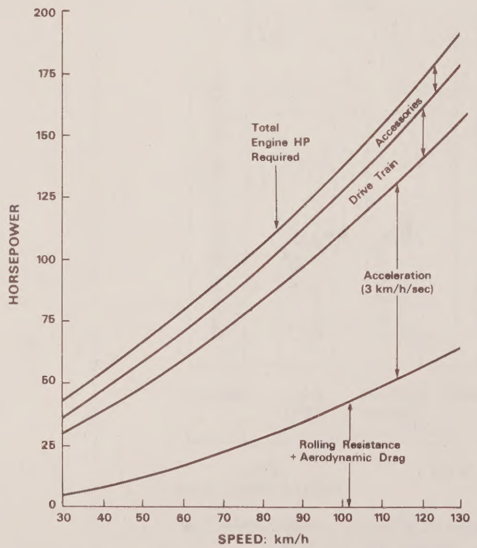
For the most part, this discussion focuses on measures which can be introduced immediately and at very little cost. In all cases the fuel conservation measures described are specifically aimed at saving fuel in urban driving conditions. They do not touch upon techniques designed for high-speed highway driving such as aerodynamic devices.

1- Fleet Operations

Municipal vehicles are driven primarily in downtown or suburban streets, in traffic conditions characterized by stop-and-go movements, frequent periods of idling, low average travel speeds and relatively short-distance trips. These factors contribute to very high fuel consumption. Transport Canada fuel ratings[1]* show that urban driving fuel consumption is typically 20 to 30% higher than the average, and more than 50% higher than constant highway driving at posted speed limits. Therefore, it is important that municipal vehicles operate at peak efficiency.

TABLE 2

EFFECT OF SPEED ON POWER REQUIREMENTS



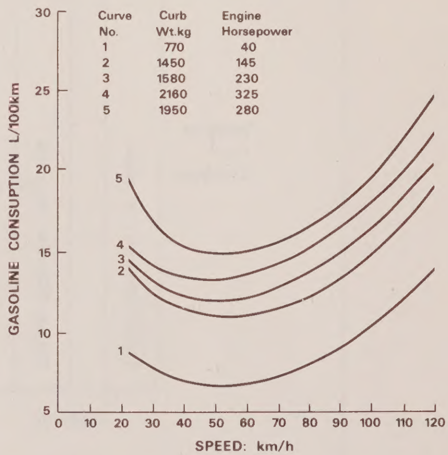
Source: U.S. Environmental Protection Agency, "Factors Affecting Automotive Fuel Economy", 1976.

Energy saving driving practices

If drivers are motivated to do so, and know how to go about it, they can be highly successful in squeezing more kilometres from each litre of fuel. Although improvements in operating efficiency can vary considerably, fuel savings of 10 to 20% are not uncommon.[2-8] A sophisticated driver training program instituted by the McDonnell Douglas Aircraft Company (U.S.) reduced fuel consumption in its vehicle fleet by an average of 22.1% per driver[9]. In Canada, driver training programs to conserve fuel have also been instituted by a number of organizations (e.g. Bell Canada and the Department of National Defence.)

TABLE 3

TYPICAL FUEL CONSUMPTION – SPEED CURVES OF PASSENGER CARS FOR CONSTANT SPEED LEVEL TANGENT



Source: Winfrey, R., "Economic Analysis for Highways", International Textbook Co., PA., 1969.

* Raised numbers refer to sources listed in the bibliography.

Steps to improve driver motivation are an important element in any program to improve fuel economy. The need to drive for greater energy efficiency must be explained, and drivers should be given incentives for reducing fuel consumption and clear recognition when goals are achieved.

Secondly, a system for monitoring fuel use by consumption of each driver will enable both management and drivers to see the results of improved driving habits. Unless these two elements - motivation and performance feedback - are firmly entrenched in a fleet fuel management program, the potential benefits from other measures will not be realized and both money and time will be wasted.

Drivers of municipal vehicles also must know what fuel efficient driving involves. It may not be practical for smaller municipalities to start their own driver training programs. There are many simple practices, however, that drivers can adopt without additional training. These include:

- Anticipating Stops - Studies have shown that in stop-and-go urban traffic fuel economy improvements of up to 8% can be achieved by anticipating stops and decelerating slowly.[8] This reduces energy "lost" through braking.

- Proper Gear Shifting - Drivers should always start out in first gear and accelerate only until the vehicle has sufficient momentum to engage the next higher gear. "Lugging" the engine increases speed, but disproportionately to fuel flow, resulting in raw fuel being passed into the exhaust system where it is burned and spewed out as black smoke. Lugging can also cause engine overloading and speed up wear.

- Keeping Speeds Down - The horsepower needed to overcome both air and rolling resistance increases with speed. As shown in Table 2 the increase in horsepower required to increase speed a specific amount is even more pronounced at higher speeds. Tests have shown that a driver uses 10 to 15% less fuel at a steady speed of 65 km/h than at 80 km/h.

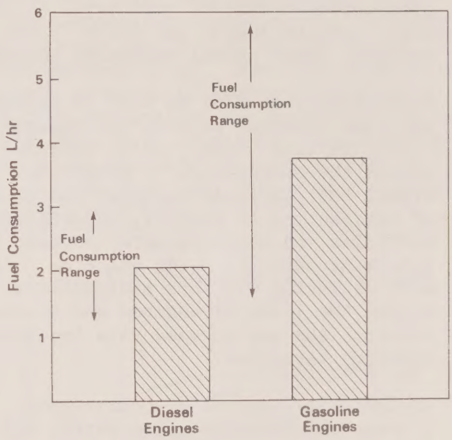
- Reducing Cruising Engine Revolutions Per Minute RPM - For peak efficiency, cruising speed should be the lowest RPM in the truck's operating range.

- Reducing Unnecessary Idling Times - For trucks and buses in urban areas, time spent idling often represents from 20 to 40% of total operating time, depending on the route and on traffic conditions. Under idling conditions a diesel engine will use about 1.8 litres of fuel per hour and a gasoline engine will use about 3.6 litres per hour.[4,13]

  Over the course of a year this amounts to a significant waste of energy, money and fuel. For example, a big truck operating in city driving conditions will waste more than 2,000 litres of gasoline (1,200 litres of diesel) through idling. Therefore, even a 10% reduction in idle time will yield considerable savings.

TABLE 4

FUEL CONSUMPTION DURING IDLING



Source: Voluntary Truck and Bus Fuel Economy Program, U.S. Department of Transportation.

Fuel-saving driving habits like these conserve more than just fuel. Proper driving skills significantly reduce other costs involved in purchasing and maintaining a fleet by reducing tire wear, increasing the intervals between maintenance, and extending the life of the vehicle.

Maintenance

Regular maintenance is another important factor in achieving good fuel economy. Some

maintenance items are particularly important in terms of energy savings:

- Engine Tune-Ups - A properly tuned engine is the key to optimum fuel consumption. Improperly tuned, an engine wastes from 4 to 10% of its fuel.[8,15] To ensure maximum operating efficiency, the air intake system should be checked regularly: dirty filters restrict the amount of air reaching the engine, thereby causing incomplete combustion and wasting fuel. Faulty connections along the fuel line and improper calibration of the fuel system (valves and injectors) can also reduce fuel efficiency.

  Proper instruments should be used instead of relying on the mechanic's judgement during tune-ups. For instance, a chassis dynamometer can identify problems mechanics may not be able to detect. Used instead of the once-around-the-block road test, it can help identify engine and drive train problems under normal operating speeds.

  Instruments can also be used to optimize the time interval between oil changes which, in some cases, can be extended beyond the manufacturer's specifications. Oil analysis measures the extent of oxidization of the oil, detects metal particles and measures water content to determine when oil needs changing. As well as saving oil, oil analysis will extend the lives of engines and transmissions and can be used as a trouble-shooting technique.

  In the past, because of collection, storage and transportation costs, oil recycling has not been common. However, with an in-house unit used motor oil can be reclaimed for use in older vehicles and for topping up between changes. Where a municipality has a sizable fleet these devices can pay for themselves in a relatively short time.

- Tires - Improperly aligned and under-inflated tires result in fuel losses through increased rolling resistance. Tests carried out in the United States have measured the impact of under-inflation on large tractor-trailers and found fuel economy improvements of 1 to 6%.[8,9,16] In one case a 9.7% fuel economy improvement was achieved by increasing pressures from 65 psi to the manufacturer's specified pressure of 100 psi. Proper inflation and alignment not only save fuel but prevent tires from wearing out prematurely.

- Preventative Maintenance Programs - Instead of attending to vehicles only in response to problems, preventative maintenance programs should be instituted. Most defects and problems are not attended to until they have noticeably affected vehicle performance, and this in turn means that the vehicles have been running at less than peak efficiency.

  The Regional Municipality of Ottawa-Carleton has a systematic preventative maintenance program which includes five stages:

  1. Drivers check and add lubricants, etc. daily.
  2. Main moving components are greased weekly.
  3. An "A" service check is done once a month, which includes grease, oil, lights and minor repairs.
  4. A "B" service is done every two months, which includes grease, oil, filters, lights, fanbelts.
  5. The standard Ontario Provincial Safety Check is carried out twice a year (full brake inspection once a year).

- Enforcement - Unless new fuel management procedures are followed, there is little point in establishing a detailed preventative maintenance program and investing in tune-up instruments. Therefore steps must be taken to monitor drivers as well as mechanics, with corrective action when necessary.

Efficient use of vehicles

Using vehicles efficiently can also lead to significant fuel savings. Because municipal size and services vary greatly from one community to another, however, it is difficult to provide estimates of potential fuel savings. Nevertheless, since the following measures involve no expenditure on new equipment, add-on devices or training programs, the savings are "free". All that is required is additional planning.

- Consolidating Loads - Carrying more payload per trip reduces the number of times the weight of the truck itself is transported. Thus, the amount of fuel needed to transport each ton of payload

is reduced. For example, Ottawa-Carleton has converted a number of sand-spreader units by installing ten-yard capacity boxes on large GVW trucks. This enables the spreader units to cover a much larger territory without having to return as often for refills. Greater savings are possible by operating at increased payloads than by any other method.

Garbage collection is another operation that should be reviewed with load consolidation in mind. For environmental reasons land-fill sites are generally located at some distance from built-up areas. It may be possible, however, to compact large amounts of garbage at centrally located transfer stations for subsequent transport by large, highly efficient vehicles to landfill sites.

- Optimizing Payload Capacity - Matching the weight or volume of the load to be transported with the payload capacity of the vehicles available is also important. In other words, a dump truck should never be used to pick up a few materials if a pickup truck will do. The degree of flexibility for optimizing the payload capacity is much greater for municipalities with large fleets and a wide range of vehicle types.

- Optimizing Routes - Reviewing the routing of each trip can eliminate unnecessary return journeys. In large municipalities pickups and deliveries should be avoided during peak hours when vehicles spend a high proportion of their time idling.

- Radio Dispatch - Using telecommunication systems, extra trips can be avoided by altering routes or vehicle duties during peak hours when idling times are the longest.

- Decentralization - Decentralizing the location of various municipal facilities associated with fleet operations can also save fuel. Many unproductive kilometres are needlessly travelled to maintenance garages, patrol garages, fuel depots, snow dump areas and other centralized facilities. Another alternative is to adopt a credit card system to permit vehicles to be refuelled at designated retail outlets.

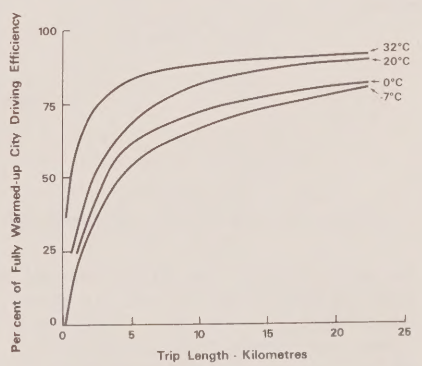
- Winter Operations - Snow clearing, salting and sanding practices should be reviewed since a reduction in frequency may result in fuel saving with little or no loss of safety. On the other hand such savings could be illusory and should be assessed carefully. For instance surveys have indicated that a reduction in snow removal may cause a net increase in fuel consumption due to increased rolling resistance of vehicle tires in snow. One survey taken in Milwaukee indicated that 18 litres of additional fuel would be consumed for each litre of fuel saved as a result of reductions in snow clearance operations.

Cold weather operations

Because most Canadian municipalities experience cold winters, the effect of low temperatures on vehicle operation deserves special attention. A vehicle does not operate at its peak efficiency until all its components (e.g. tires, engine, transmission and wheel bearings) reach their designed operating temperatures. Relative fuel consumption is high at low engine operating conditions. When the temperature is -20°C compared to summer conditions of 15°C fuel consumption for an automobile can double for a half hour trip. Since trips in urban areas generally take less than 30 minutes, the fuel loss during cold weather is quite significant.

TABLE 5

EFFECT OF TEMPERATURE ON FUEL ECONOMY



Source: "Customer Fuel Economy Estimated from Engineering Tests", Automotive Fuel Economy, Progress in Technology Series, Vol.15, 1976.

A number of steps can be taken to save fuel:

- The use of block heaters coupled with timers can be very cost effective. A block heater allows the engine to

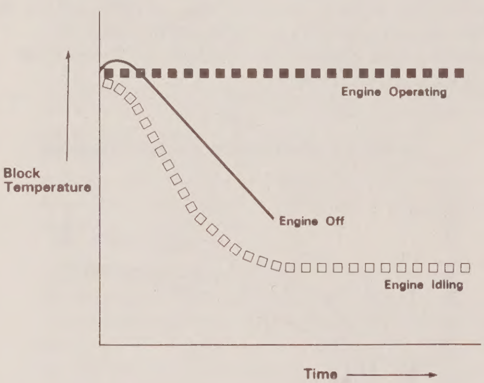
approach summer performance more quickly by maintaining the block above ambient temperature. With timing units connected to the heaters, the amount of electrical energy consumed is minimal compared to the number of litres of fuel saved.

- Where municipal vehicles are stored indoors heated storage areas may not be necessary. Mechanically-sound vehicles can be kept in cold storage structures, while only vehicles needing repairs are brought into a heated service shop.

- Contrary to popular belief, idling a vehicle during pick-ups and deliveries does not keep the engine warm. An engine will cool off faster when it is left idling than when it is shut off. This is because heat is pulled from an idling engine by the continued operation of the cooling and exhaust systems. Since these systems stop operating when the engine stops, turning the engine off retains more heat over the short term than leaving it idling.

TABLE 6

REDUCTION IN BLOCK TEMPERATURE OVER TIME



Source: General Motors Corporation, "Truck Selection", 1977.

- Demand actuated fans allow the engine to heat up faster and prevent it from over-cooling in winter. Tests have shown that these fans increase fuel efficiency by several percentage points. Radiator shutters can increase efficiency by about 2%.

- Short trips should be avoided by consolidating several trips and routes into as few as possible.

Fuel management

A fuel management program should account for the consumption of every litre of gasoline purchased by a municipality. Although not in itself fuel-saving, such a system will help fleet managers assess measures to improve fuel efficiency and uncover excessive consumption, whether due to defective equipment, inadequate maintenance or unsuitable driving behaviour.

- <u>Monitoring Fuel Consumption</u> - As a first step, the fuel consumption of each vehicle can be monitored by carefully recording the odometer reading and the number of litres required every time a vehicle is refuelled.

  More sophisticated methods involve installation of instruments such as tachographs, which are effective in recording fuel-wasting driving habits such as excessive speed, panic stops and rapid acceleration.

  Recently small in-cab computers have become available. These digital fuel meters provide drivers with instant feedback in response to their driving habits.

  Municipalities should consider installing fuel dispensing facilities at their yards and patrol garages. This will ensure that careful records are kept of fuel consumption by each vehicle and will also eliminate pilferage.

  Fuel records provide the basis for good management decisions and are an important part of driver incentive programs. The fact that strict records are being kept in itself encourages everyone in the organization to save fuel.

- **Revised Purchasing Policies** - Municipalities that have their own fuel-dispensing facilities can also revise their fuel purchasing policies, by accepting summer (hot weather) deliveries during the mornings only to minimize evaporation losses, and by recording fuel deliveries by weight, rather than by litres. In the case of summer deliveries, weight recording is more accurate than litre measures, particularly if the fuel is delivered early in the morning when temperatures are cool and the fuel has not had the opportunity to expand. McDonnell Douglas estimated that they get an extra 2250 litres of fuel a month by following these rules.

2- Equipment Selection

Whether new replacement vehicles are purchased annually or only occasionally, it is important to be aware of the options available now and in the future for improving fuel economy. When setting specifications for new equipment, fleet managers should bear in mind that fuel economy is closely related to engine power load (horsepower) and engine efficiency.

TABLE 7

MUNICIPAL VEHICLE TYPES, WEIGHTS AND FUEL CONSUMPTION

Vehicle Type		Weight (kg)	Typical Urban Fuel Consumption (L/100km)[1]
Automobile	Subcompact	under 1150	10[2]
	Compact	1150- 1500	9-12
	Intermediate	1500- 1650	11-13
	Full Size	over 1650	12
Truck	Light	under 4500	18-30[3]
	Medium	4500- 8900	36-44
	Light-Heavy	8900-11800	37-47
	Heavy	over 11800	36-69 (diesel)
Bus	Van	under 4500	approx 19
	Mini	4500- 8900	N.A.
	School	over 11800	43-52
	Transit	over 11800	approx 44 (diesel)

1. Calculation: $X \text{ mpg} = \frac{282.5 \text{ L/100km}}{X}$

2. Automobile test fuel ratings reported by Transport Canada [1]

3. Truck and bus in-use fuel consumption as reported by various operators. See references [2,3,4,5,6].

Engine power load

To move any vehicle an engine must provide power to overcome the following vehicle loads:

- o Rolling friction
- o Drive train losses
- o Air resistance
- o Accessories

Table 2 illustrates the relative importance of these loads at various vehicle speeds. At the low speeds typical of urban driving conditions, engine load is due primarily to the effect of rolling friction. Air resistance only becomes significant at speeds above 50 km/h. In all cases, however, steps can be taken to increase energy efficiency.

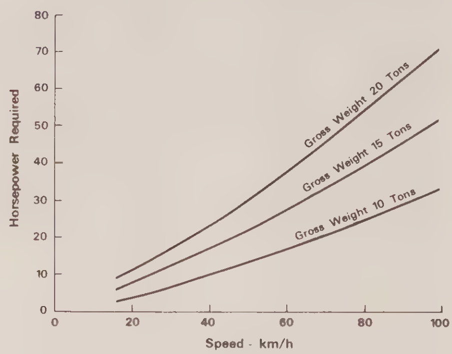
o <u>Reducing Rolling Friction</u> - Rolling friction is the power lost in tires and bearings. Both vehicle weight and tire characteristics affect rolling friction, and these are two factors that should be considered carefully in equipment selection.

- Reduced Curb Weight - Purchasing lighter vehicles is one of the best ways of saving fuel. When buying passenger cars, municipalities should consider substituting a compact or even a subcompact for a heavy full size car. While the better fuel economy in compact and subcompact cars is partially attributable to smaller engines, it should be recognized that weight influences fuel consumption more than any other single factor. As for trucks, those vehicles which are normally loaded to far less than their full capacity could be replaced with smaller and lighter models.

- Radial versus Standard Tires - All tires absorb a considerable amount of power as they roll and flex during vehicle operation. Since radial tires absorb less power than ordinary bias ply tires, however, their use can result in lower fuel consumption. The potential fuel savings vary with the type of vehicle and its driving cycle. It should be noted however that sidewall failure of radial tires in urban areas, where vehicles may rub up against curbs, must be considered when weighing the advantages of their longer life and fuel savings.

TABLE 8

RELATIONSHIP BETWEEN SPEED AND HORSEPOWER REQUIRED TO OVERCOME ROLLING RESISTANCE AND GROSS VEHICLE WEIGHT



Source: General Motors Corporation, "Truck Selection", 1977

o <u>Reducing Power Losses in the Drive Train</u> - Inefficiencies in drive train components represent a power loss which must be compensated for by the engine. Drive train components vary among vehicle types of the same size and classification, however, and through proper specification fuel savings are possible.

- Manual versus Automatic Transmissions - If driven properly, manual transmissions offer better fuel economy than automatic transmissions - typically, under test conditions a 10% improvement is possible with a small car. Specification of a manual transmission for passenger cars in the fleet can therefore save fuel.

  Any decision to purchase manual instead of automatic transmissions should take into account the number of people who will be driving the vehicle, their training and the type of driving conditions. Potential savings from a manual transmission will not be achieved if the vehicle is driven so that the gears do not engage correctly (lugging or overspeeding the engine).

  If there is only one driver assigned to the vehicle, and he has received good training, then a manual transmission should be considered.

TABLE 9 FUEL SAVINGS WITH RADIAL TIRES BY VEHICLE TYPE AND DRIVING CYCLE		
Vehicle Type	Driving Cycle Local	 Short-haul
	per cent	
Medium Duty (Classes III-V)	3-9	4- 9
Light Heavy Duty (Class VI)	3-8	5-10
Van (10 Tonnes)	0	1.4
Heavy Duty (Classes VII-VIII)	3-8	5-10
Dump Truck (28 Tonnes)	8.4	6.0

Frequent shifting in congested traffic, however, combined with the effects of fatigue from a long day at the wheel, make it unlikely that potential fuel savings will be fully realized. Furthermore, if the vehicle is used by a number of drivers it will be more difficult to ensure that it is driven efficiently, particularly if these drivers have not had much experience with manual transmissions. In these cases it may be more prudent to select an automatic transmission.

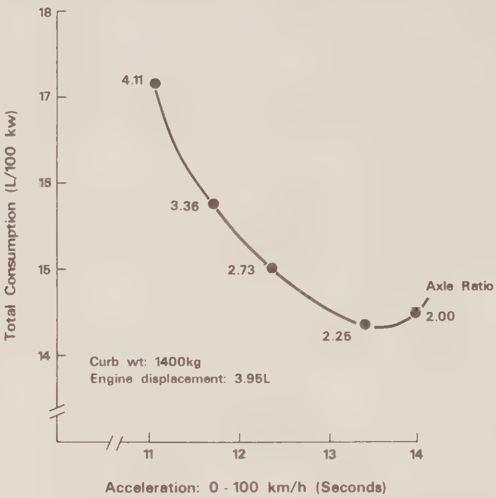
- Improved Automatic Transmissions - Fuel economy from automatic transmissions can be maximized by specifying a higher number of gears, four or five where available, instead of the conventional two or three. The additional gears permit better automatic matching of engine speed and torque with the horsepower demanded. A 5% improvement in passenger car fuel economy can be achieved through the use of a 4-speed automatic instead of a 3-speed. Many subcompact cars are now available with 4-speed automatic transmissions.

  Fuel economy can be improved further through the use of a torque converter lock-up. This device eliminates the torque converter slippage normally experienced during cruise. Four or five speed automatic transmissions with torque converter lock-ups are becoming available in transit and school buses, and fuel savings of 10 to 20% are expected.[3,20] Although not presently available on all types of light vehicles, torque converter lock-ups can be obtained on some passenger cars. In these cases they improve fuel economy by about 6%. Torque converter lock-ups are expected to become increasingly available in light trucks and automobiles in the near future.

- Lower Axle Ratios - Depending upon the present gearing of the vehicles, a substantial gain in fuel economy may be achieved by lowering the rear axle ratios. The lower axle ratio

TABLE 10

TRADE-OFF OF FUEL CONSUMPTION AND PERFORMANCE FOR VARIOUS REAR AXLE RATIOS



Source: "Car Design for Economy and Emissions", Automotive Fuel Economy, Progress in Technology Series, Vol.15, 1976.

reduces the engine speed necessary to propel the vehicle at a chosen road speed, and fuel savings of up to 5% are possible for trips involving a mixture of urban and highway driving conditions.[3,21]

As the table shows, moving to a lower axle ratio does result in some loss of acceleration. In terms of trip time, however, this effect is insignificant.

- Tag Axles - Some large trucks (e.g. dump trucks) have tandem rear axles which consume power. Tests have shown that a 2-4% improvement in fuel economy can be obtained by changing to a unit with a single driven axle and a non-driven (tag) axle.[3] Some loss in traction is experienced with this type of arrangement, although this may only be important in off-road use such as gravel hauling.

- Reducing Air Resistance - As shown in Table 2, at urban driving speeds air resistance places much less demand on the engine load than rolling friction. Therefore, the effectiveness of devices which conserve fuel by reducing air resistance depends upon the driving cycle of each vehicle. Unless a truck does a significant amount of non-stop highway driving, the use of aerodynamic drag reduction devices will reduce fuel consumption by only 1 to 2%.[3]

  At high average travel speeds, fuel economy studies have shown that drag reduction devices can reduce fuel consumption by 3 to 10%.[3,4] Wind deflectors are ineffective, however, and can increase fuel consumption if used on truck units where the cab height is higher than the rear portion of the truck.

- Demand-Actuated Radiator Cooling Fan - The fan is the largest single contributor to the accessory load of any vehicle, yet under most operating conditions the fan is not needed more than 35% of the time that the engine is running. The actual amount of time fan operation is required depends upon several factors.

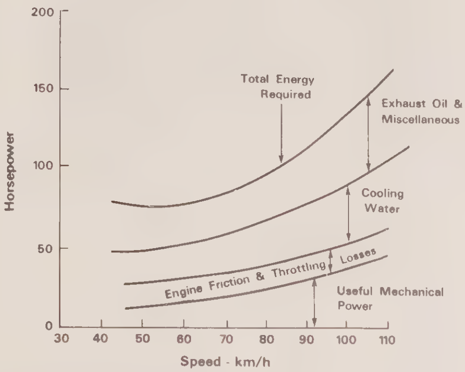
  In the stop-and-go driving assumed to be typical of most municipal vehicles, fan operation is required more than during speed driving conditions. On the other hand the fan is required less during cool weather, an important factor in Canadian municipalities.

  Since operation of the fan is unnecessary for most of the time that an engine is running, the engine is unnecessarily cooled and the fuel required to operate the fan is wasted. With a temperature actuated variable speed fan drive, or fan clutch as it is commonly known, fuel savings of 4 to 7% are possible for trucks being driven in urban traffic conditions.[3,4] An added benefit from the use of clutch fans is that the noise level lowers when the fan is not in operation.

o <u>Engine Efficiency</u> - The efficiency of an engine determines the percentage of the combustion energy which ends up as mechanical power output. Only 10 to 30% of this energy is converted to mechanical power; most of the remainder is carried away in the exhaust and cooling water.

TABLE 11

ENERGY DISTRIBUTION, FULL SIZE AUTO ENGINE



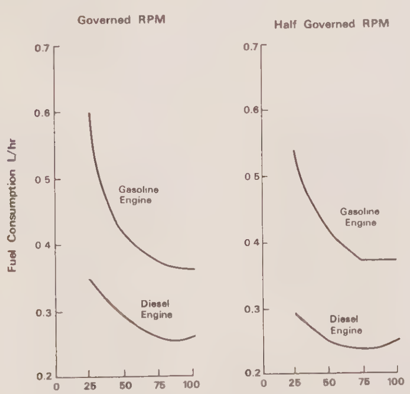
Source: U.S. Environmental Protection Agency, "Factors Affecting Automotive Fuel Economy", 1976.

Steps can be taken at the time of purchase to ensure that new vehicles operate at maximum engine efficiency.

- Diesel versus Gasoline Engines - As shown in Table 12, the substitution of diesel for gasoline engines can result in significant fuel savings. Operating at much higher pressures and temperatures, diesel engines burn fuel more efficiently and diesel fuel contains about 12% more energy than an equal volume of gasoline.

TABLE 12

ENGINE FUEL ECONOMY OF VARYING SPEEDS AND LOAD



Source: "Encouraging School Transportation Effective Energy Management (ESTEEM)", U. S. Department of Transportation, 1977.

The relative efficiency of diesel engines is even more pronounced under urban stop-and-go driving conditions. While this type of driving tends to make gasoline engines overheat, diesel engines are built to withstand the higher internal pressures involved. Furthermore, diesels consume less fuel while idling since they idle at lower speeds. See Table 4. Under urban driving conditions fuel savings of 20 to 40% are possible by substituting diesel for gasoline engines (See references 2,3,4,5, 13,16).

A comparison by the municipality of Ottawa-Carleton of fuel consumption by their diesel and gasoline half-ton pick-up and spreader units showed improvements in fuel economy of 78% to 83% with the diesel units.

Until recently, diesel engines have been available only for medium and heavy trucks. As fuel prices continue to rise, however, the availability of diesel engines in light trucks and passenger cars will increase. Although the initial cost of a diesel is higher than the cost of a similar vehicle with a gasoline engine, diesels are usually cheaper in the long run. Diesel engines produce considerable cost savings not only in fuel but also in maintenance because of their superior durability and reliability.

- Propane - Propane, which is produced as a byproduct of natural gas processing and oil refining, is relatively abundant in Canada. Therefore, substituting propane for gasoline in transportation offers an important opportunity to offset reliance on imported oil.

Demonstration experiments with propane are being conducted in a number of Canadian cities, principally in western Canada where propane can be purchased cheaply. These experiments include police cars in West Vancouver and taxis in Calgary that will operate on propane fuel.

The federal government's National Energy Program provides incentives of up to $400 per vehicle for the

conversion of commercial, agricultural and municipal fleets to propane.*

In addition, the Ontario government recently launched a program called "Drive Propane" to encourage commercial fleet conversion, and this program is given much impetus by the removal of the 21 cent per gallon provincial road tax for alternative fuels.

The Department of National Defence has also announced its intention to convert a significant portion of its fleet to propane fuel.

Conversion costs range from $1,200 to $2,000 per vehicle, half related to equipment, the remainder to labour. These costs could be reduced significantly by increasing the volume, and if new vehicles are manufactured with propane fuel engines the additional cost could be as low as $300 per unit.

Propane prices vary widely in Canada, low in the west and higher in eastern and central Canada. The development of a significant transportation demand for propane should stabilize prices by reducing the seasonal demand fluctuations, and by insulating the Canadian market somewhat from the U.S. market. Propane is available now in central Canada and there are good prospects for propane in the Maritimes as a byproduct of gas production from Canada's east coast.

Fuel consumption in a propane-powered car can range from being equivalent to gasoline engines to being about 10 percent higher, depending on the type of conversion and vehicle. Propane-powered engines offer a number of benefits:

- increased engine life
- increased lubricating oil life
- increased spark plug life
- reduction in down-time

* For further information, contact the Propane Vehicle Grant Program Office, 580 Booth Street, Ottawa K1A 0E4

- Turbocharging - Turbocharging increases the available power of an engine by using exhaust gas to drive a turbine, connected to an impeller, which then delivers excess air to the cylinders. A turbocharged engine will achieve higher temperatures and pressures than a comparably powered, larger, non-turbocharged engine. The higher engine efficiency results in fuel savings of up to 10% for diesel engines and 15 to 20% for gasoline engines under local driving conditions.[3,4,13,15]

- Derating The Engine - This is a simple procedure to reduce the available horsepower in diesel engines: the fuel injectors are calibrated to deliver less fuel than is required to produce maximum rated or design horsepower. Provided that the lower horsepower is adequate for the tasks which the vehicle is to perform, derating the engine will lengthen engine life, reduce maintenance costs and result in fuel savings of 2 to 5%.[3,13] Derating can be done on existing fleet vehicles and can be specified when new vehicles are purchased. Derated engines can be recalibrated to the original horsepower rating if necessary at relatively low cost.

- Reducing Diesel Engine Speed (RPM) - Conventional diesel engines are generally designed to operate at a maximum engine speed of about 2,100 rpm, at which point the governor limits fuel flow to the engine and prevents further increases in engine speed. Optimum fuel efficiency, however, usually occurs in the operating area of 1,600-1,800 rpm. Therefore, one method for improving fuel economy is to train drivers to cruise at about 20% below governed speed in top gear. Alternatively, an adjustment can be made to the governor, forcing the driver to operate the engine closer to the optimum fuel efficient speed.

  Fuel savings of 7 to 10% are possible by reducing the engine speed.[3,13] However this must be traded off against slightly longer trip times and, more important, increased frequency of shifting.

- Fuel Injection - The mixing of air and fuel for most gasoline engines is performed by a single central device, the carburetor. The air/fuel mixture is then distributed to the cylinders. Sometimes, however, this mixture is not distributed equally to all cylinders, causing lean fuel zones and misfiring unless excess fuel is provided by the carburetor. With fuel injectors for each cylinder these problems are avoided. Studies have shown that fuel savings of up to 10% have been achieved by specifying fuel injection systems instead of carburetors on gasoline engines.[2,3,4]

Evaluation of vehicle operating costs

Many of the fuel-saving accessories described so far will add to the initial price of a vehicle but will result in lower fuel costs. Depending on the option, they may also result in higher or lower maintenance costs over the life of the vehicle. The cost effectiveness of fuel-saving accessories must be evaluated by considering all affected costs over the life of the vehicle, and not merely the purchase price.

Vehicle operating costs normally consist of the following items:

- fuel and oil
- maintenance & repairs (engine and body)
- tire replacement
- licence
- insurance
- parking and garaging

Ignoring licence, insurance and parking costs, which are unlikely to vary with the type of fuel-saving accessories selected, decisions affecting equipment will involve a trade-off between:

Change in vehicle purchase price (or cost of retrofitted equipment) depreciated over period vehicle is owned. (+)	vs.	Change in annual costs of fuel and oil maintenance and repairs, tire replacement (-)

This calculation should be made on an annual (or per km) basis over the life of the vehicle or equipment. Much of the information needed to calculate total operating costs should be available from equipment suppliers. Section 4 in this series of booklets, "Financial Analysis of Conservation Opportunities", discusses techniques which can be used to analyze the cost effectiveness of conservation measures.

The following example illustrates this principle:

DIESEL VERSUS GASOLINE ENGINE
MEDIUM-SIZED TRUCK

- Calculation of Savings (simple payback)

Total savings (fuel and maintenance) per annum from purchase of diesel	$ 1414
Additional investment	$ 3300
Simple payback period 2.33 years (3300 - 1414)	

- Calculation of Net Present Value*

Vehicle life years	10
Present worth of annual savings, using a discount rate of 12%	$7,989
Present worth of investment	3,300
Net present value	$4,689

Clearly, the value of the energy and maintenance savings justify the additional expenditure.

* No allowance for salvage values. Net Present Value in this case means the value of total savings resulting from this investment over the 10-year life of the vehicle, expressed in today's dollars.

A final note

When purchasing new equipment don't overlook the purchasing process itself. The equipment supplier should be given as much information as possible on how each vehicle will be used and under what conditions. The average hauling distance will be relevant, as will speeds required, the size, weight and type of commodities to be transported, the roads the vehicles will be operating on, and the training of the drivers. Finally, ensure that any options requested are absolutely necessary and that servicing facilities are available.

3- Summary

The fuel improvement measures presented in this section are summarized on the following page, along with an estimate of the savings they offer. These estimates, however, are drawn from results of scientific testing and the experience of various fleet operators. Actual savings for a specific municipality will depend on factors unique to each community (e.g. climate, population density and topography.) Nor are the savings cumulative. In addition not all these measures will be applicable to every municipality. Finally, many fleet managers will already have taken steps to reduce fuel consumption by implementing various techniques that have been discussed.

What is clear, from research and growing experience in the field, is that increased attention to good driving habits, sound fleet and fuel management, and careful equipment selection will result in important fuel and dollar savings for any municipality.

Steps to take now

Fuel conserving methods which can be introduced immediately and at very little cost include:

- A system for recording and monitoring fuel consumption for all operating vehicles.
- A program to encourage fuel-conscious driving practices such as anticipating stops, proper gear shifting, the installation of tachographs, driving at lower speeds, eliminating unnecessary idling.
- More efficient vehicle utilization by consolidating loads, optimizing payload capacity and routes, and adopting fuel-efficient cold weather operations.
- Proper maintenance, including regular tune-ups, correct tire inflation and wheel alignment, and a preventative maintenance program.

Considerations when selecting new equipment

When replacing parts on vehicles and when purchasing new vehicles, consider the following:

- lighter vehicles with smaller engines
- radial tires
- the choice between manual and improved automatic transmissions
- lower axle ratios
- tag axles for heavy trucks
- specifying only fuel-efficient accessories (e.g. a demand actuated fan)
- substituting diesel or propane for gasoline engines
- improving engine efficiency through turbocharging, derating, reducing engine speed, and fuel injection
- stratified charge engines

TABLE 13

SUMMARY OF FUEL - CONSERVING MEASURES

1. FLEET OPERATIONS

Measure	Reported Savings (percent)*
o Energy Saving Driving Practices (e.g., anticipating stops, proper gear-shifting, keeping speeds down, eliminating unnecessary idling)	10-20
o Proper Maintenance	
- regular tune-ups	4-10
- correct tire inflation	1- 6
- preventative maintenance	-
o Better Vehicle Utilization	-
- consolidate loads, optimize capacity, improved scheduling and cold weather operations.	

2. EQUIPMENT SELECTION

Measure	Reported Savings (percent)*
o Reducing Engine Powerload	
- reduced curb weight	-
- radial tires	3-10
- manual vs. automatic transmissions	-
- improved automatic transmissions:	
4 or 5 gears	5
torque converter lock-up (buses)	10-20
(cars)	6
- lower axle ratios up to	5
- tag axles	2- 4
- aerodynamic devices	1- 2
- temperature actuated cooling fan	4- 7
- radiator shutters	2
o Improved Engine Efficiency	
- substitution of diesel for gasoline engines	20-40
- turbocharging: diesel	up to 10
gasoline	15-20
- engine derating	2- 5
- reducing engine speed	7-10
- fuel injection	up to 10

* Figures taken from text

4- Sources

The bibliography which follows provides sources for more detailed information on the various measures discussed here. At present, unfortunately, there are no widely available technical manuals on energy efficient fleet management, although the references provide useful information on specific measures.

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